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Original Paper

Effect of season and temperature before and after calving on the future milk production of born heifers

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The aim of the study was to evaluate the effect of birth season, average maximum temperatures 6 weeks before and after birth of heifers on their first lactation milk yield. In chosen herd, the effect of birth weight, weight gain until weaning on first lactation milk yield was also investigated. Additionally, the effect of the average maximum temperatures before birth, effect of birth season on birth weight were evaluated. The data were collected from the herd "A" in Orava region consisting of Slovak spotted breed (127 records), the herd "B" in Lower Nitra (150 records) and herd "C" in Upper Nitra (116 records) both consisting of black Holstein Friesian cows. Birth season tended to influence the heifers first lactation milk yield in the herd "C" (P <0.06). The maximum average temperatures during the first 6 weeks after birth significantly affected heifers first lactation in the herd "A" (P <0.01). The maximum average temperatures affecting pregnant cows before birth of their heifers did not influence heifers' milk yield during the first lactation in all herds (P >0.66, herd "A"; P >0.59, herd "B"; P >0.38, herd "C"). In the herd "B" there was insignificant effect of prenatal temperatures, birth season on birth weight of heifers (P >0.97; P >0.74). However, the heifers with the highest weight gains until weaning had numerically higher first lactation milk yield (P >0.20).

Keywords: dairy calves, temperature, season, milk yield, gestation length

1 Introduction

Decades of dairy cattle genetic selection considerably improved milk production (Miglior et al., 2017) and their functional traits (health, reproduction, survival) (Kasarda et al., 2018). More recently, dairy cattle genetic progress was even more accelerated by implementation of genomic selection (Wiggans et al.,2017), which brought potential of doubling genetic gain (Schaeffer, 2006). Nevertheless, it was suggested by Tao et al. (2018), that also environmental conditions might have effect on future performance of progenies by causing epigenetic modifications, that comprise heritable alterations of gene expression without DNA modification (Callinan and Feinberg, 2006), resulting in changes of metabolic phenotype of foetus (Yates et al., 2011).

In this respect, recent studies suggest that not only dry cows are substantially influenced by late gestation environmental conditions, but also their female calves (heifers) (Tao et al., 2018, Tančin et al., 2018). This might be supported by several authors, who reported in offsprings born to heat stressed dams slowed foetal development (Van Eetvelde and Opsomer, 2017), lower birth weights (Tao et al., 2012), alteration of metabolism (Monteiro et al., 2016a), reduced immunity (Monteiro et al., 2014), retarded growth (Monteiro et al., 2016b), modified thermoregulation (Laporta et al., 2017), worsened reproductive performance and lower first lactation milk yield (Monteiro et al., 2013). Monteiro et al. (2016b) proposed, that explanation for these negative effects of mothers' environment on their offsprings, might be already mentioned epigenetics and its molecular mechanisms.

Moreover, according to some authors, also conditions during calves' early life influence considerably their

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first lactation productivity (Heinrichs and Heinrichs, 2011). It was found that temperature, especially cold temperatures at birth, caused decrease in preweaning weight gain and subsequently also decrease in milk yield (Soberon et al., 2012). Furthermore, preweaning nutrition might be considered as very important factor, as Soberon et al. (2013) and Uhrinčať et al. (2007) confirmed that preweaning average daily weight gain was significantly associated with first lactation milk production. This might indicate that epigenetic programming occurs also during preweaning period (Soberon et al., 2012). In addition, it was observed that dairy cows which were as young heifers fed by whole milk had higher milk yields (Moallem et al., 2010) and better endocrine status expressed by higher thyroid hormones concentrations (Tančin et al., 1994) compared to young heifers fed with milk replacer.

Nevertheless, some authors assume that also photoperiod may explain changes in milk yield (Rius and Dahl, 2006). This can be partially supported by study of Osborne et al. (2007), who found that long day photoperiod may influence preweaning growth of calves, which may be according to Dahl et al. (2012) associated with higher milk yields on their first lactation.

Therefore, the objective of this study was to examine the effect of prenatal and postnatal environmental conditions, particularly temperatures and seasons, but also birth weights, average daily weight gains until weaning of heifers, on their milk production during first lactation under practical conditions.

2 Materials and methods

2.1 Animals, management and environment

The analysed data (393 records) were obtained from three dairy farms, of which herd "A" was located in Orava region (Northern Slovakia), herd "B" in region of Upper Nitra (Western Slovakia) and herd "C" in Lower Nitra region (Western Slovakia). The herd "A" (127 records) consisted of Slovak spotted breed, the herd "B" (150 records) and the herd "C" (116 records) comprised of Holstein Friesian cows. Dairy cows in the herd "A" and "C" were kept in free housing system. Animals in the herd "B" were housed in boxes. Fans were not used on neither of the farms during the dry period. In all farms the calves were separated from dams shortly after parturition and placed into calf's pen outside. Calves on farm "A" were first two weeks housed in calf's pen individually and fed by acidified native milk and consequently moved to group with automatic milk feeder and fed by milk replacer. Calves on "B" and "C" farms were during whole period of milk nutrition housed individually in calf's pen and fed by milk replacer. On farm "B" the intake of milk replacer by calves was increased by 30% if the outside temperature was lower than 5 °C. In another two farms the amount of milk offered to calves was the same during whole year. Only on farm "B", there were available data of body weight to calculate daily gain and weight at weaning.

The average yearly environmental temperatures in Orava region (Herd "A") were 4–6 °C, the farms in regions of Upper and Lower Nitra (Herd "B" and "C") were affected by milder temperatures in range of 8–9 °C.

2.2 Data and statistical analysis

The data in the herd "A" were collected in years 2006-2017, where most animals were concentrated in years 2010–2017. In the herd "B" the data were acquired in years 2014–2018 and in the herd "C" in years 2014–2016. The animals that were enrolled into the study were heifers with finished first lactation.

The statistical analysis was done using SAS® software (SAS Studio 3.8, 2018). The distribution normality was examined using the Shapiro-Wilk test. The investigated variable (305-d milk yield) was analysed by general linear model (PROC GLM), that included fixed effects of dams' parity (3 categories, first, second, third and more) sex of the calves (3 categories, males, females, twins), birth season (4 categories, Winter – December to February, Spring – March to May, Summer – June to August, Autumn – September to November), the average maximum temperatures 6 weeks before birth (4 categories, below 5 °C, 5.1–14 °C, 14.1–20 °C above 20 °C), the average maximum temperatures 6 weeks after birth (4 categories, below 5 °C, 5.1–14 °C, 14.1–20 °C above 20 °C). In the herd "B" there were as fixed effects included also birth weight (5 categories, bellow 39 kg, 39.1–42 kg, 42.1–44 kg, 44.1–47 kg, above 47 kg) weaning weight (5 categories, bellow 100 kg, 100.1–110 kg, 110.1–120 kg, 120.1–130 kg, above 130 kg) average daily weight gain till weaning (4 categories, bellow 0.7 kg, 0.7–0.9 kg, 0.9–1.0 kg, above 1.0 kg).

The data from herd "B" were also analysed using the nonparametric Wilcoxon's rank-sum test (PROC NPAR1WAY), where the effect of maximal temperatures 6 weeks before birth (4 categories, below 5 °C, 5.1–14 °C, 14.1–20 °C above 20 °C) and season of birth (4 categories, Winter – December to February, Spring – March to May, Summer – June to August, Autumn – September to November) on birth weight were evaluated.

The data of the herds were analysed separately. Tendency was declared at $0.05 < P < 0.1$ and statistical significance at $P < 0.05$.

3 Results and discussion

The effect of heifers' birth season on their 305-d milk yield is shown in Table 1. The effect of birth season on milk yield was found to be insignificant in the herd "A" and "B". However, in the herd "C" season of birth tended to influence milk yield (Table 1). Nevertheless, differences between seasonal milk yields in the herd "C" were not significant (Table 1) and tendency of milk yield difference was found only between spring and autumn. In the herd "A" it was observed that heifers born in hot summer season had numerically higher milk yields compared to the ones born in cold winter season, the season when heifers with the lowest milk yields were born (Table 1). Numerically comparable results were found also in the herd "B", where heifers born in warmer spring and summer seasons had higher milk yields compared to those born in winter (Table 1). Milk yields of heifers born in summer in the herd "A" were 911 kg higher compared to those born in winter. In the herd "B" the difference was 466 kg. These findings are numerically comparable with study of Van Eetvelde et al. (2017), who opined, that higher summer temperatures during the late gestation, cause birth of calves with higher peripheral insulin sensitivity and higher first lactation milk production. However, when we examined specifically effect of higher temperatures, that were affecting heifers 6 weeks before and after birth, we found some evidence pointing on negative effect of prenatal and postnatal high temperatures (Table 2). Therefore, we may assume that not all the cows that calved in summer were automatically affected by heat stress and therefore also factors proposed by other authors, like cows' social stress (Wu et al., 2006), cows' delivery score, heifers' health (Heinrichs and Heinrichs, 2011), preweaning nutrition (Soberon et al., 2013) could have played its role in affecting heifers' milk yield during first lactation in relation to season. This might be supported by our findings in the herd "C" that contradicted aforementioned data, where we observed the highest milk production in cows born in spring and the lowest milk yields in animals born in autumn (Table 1). Nevertheless, it might be affected also by higher individual variability in milk production among animals in the herd "C", with 305-d milk yield ranging from 4,302 kg to 12,800 kg.

Important role of prenatal heat stress, already suggested by Tao et al. (2018), might be numerically indicated by our observations in the herd "A" and "B" (Table 2), where we found that heifers born to cows affected by the average maximum daily temperatures above 20 °C during late gestation had lower milk yields. That partially contradicts aforementioned data illustrating milk yields in relation to seasons. Moreover, these data correspond to findings of Tao et al. (2019), who reported that heifers born to heat-stressed dry cows had lower milk yield on their first and second lactation. Likewise, Dahl et al. (2016) pointed out importance of late gestation heat stress when they indicated that even short period of heat stress might alter the performance of dairy heifers. Besides the effect of prenatal temperatures, we also examined impact of postnatal temperatures on born heifers on their 305-d milk yield (kg) (Table 2), which might be illustrated also by impact of temperatures on calves' behaviour (Vaculikova and Chladek, 2015). The significant effect of environmental temperatures after birth on heifers' first lactation milk yield was found only in the herd "A". In this herd we found that temperatures above 20 °C were related to lower milk yield, compared to all other groups of heifers. These observations are numerically comparable with milk yields of heifers, that we found in the herd "B" (Table 2). In this respect we might suggest important role of prenatal and postnatal high temperatures on performance of born heifers. Nevertheless, authors like Soberon et al. (2012) observed lower milk yields due to cold stress, that contradicts our findings in the herd "A" and "B". Moreover, also herd "C" was not comparable with aforementioned herds. As heifers in the herd "C" that were after birth affected by temperatures above 20 °C had higher milk yields compared to calves affected by lower temperatures, but that could be partially explained by aforementioned individual milk production variability of the herd "C". In this respect, mean 305-day milk yield in the herd "A" was 5,529 kg, in the herd "B" 9,402 kg and in the herd "C" 9,655 kg.

In addition, In the herd "B", we also monitored birth weight and average weight gains until weaning (Tables 3, 4, 5). In this respect, some authors observed that heifers born to heat stressed mothers had lower birth weight (Laporta et al., 2017) and worse first lactation performance (Monteiro et al., 2016b) compared to those born to cooled cows. However, in practical conditions we did not confirm that (Table 3). But we have numerically confirmed findings of Monteiro et al. (2016b) who observed connection between prenatal heat stress of cows and worsened first lactation performance of their heifers (Table 2). In Table 4 we examined effect of birth season on weight at birth, where we found very minor differences between seasons. Therefore, we may suggest that in the examined herd "B" neither high prenatal temperatures nor photoperiod affected birth weight of born heifers.

We also studied effect of daily weight gains of dams' heifers until their weaning on the first lactation milk yield, as some authors (Soberon et al., 2013) observed higher milk yields in heifers with higher weight gains until weaning. Our findings in the herd "B" (Table 5) were numerically comparable with above mentioned findings, however insignificant. As we found that heifers that in average gained more than one kilogram of weight per

Table 1 Effect of birth season on 305-d milk yield (kg) of daughters, with average maximal temperatures of seasons affecting animals before and after their birth in different farms

Season	*n*	A	Avg max temp 6 Wks		*n*	B	Avg max temp 6 Wks		*n*	C	Avg max temp 6 Wks	
			before birth (°C)	after birth (°C)			before birth (°C)	after birth (°C)			before birth (°C)	after birth (°C)
Spring	30	5,192 ±247	8 ±0.9	16 ±0.7	38	9,611 ±232	13 ±0.7	20 ±0.7	20	10,734 ±404^{a}	16 ±0.9	20 ±0.9
Summer	30	5,960 ±331	22 ±0.36	20 ±0.5	32	9,744 ±350	26 ±0.5	27 ±0.5	55	9,476 ±408^{a}	26 ±0.3	26 ±0.3
Autumn	28	5,534 ±246	16 ±0.9	9 ±1.1	41	9,384 ±253	18 ±0.7	10 ±0.7	26	9,384 ±314^{a}	20 ±0.9	13 ±1.2
Winter	39	5,049 ±306	1 ±0.4	3 ±0.5	39	9,278 ±317	6 ±0.4	7 ±0.6	15	9,895 ±460^{a}	6 ±0.4	9 ±1.0
p		<0.33	<0.001	<0.001		<0.61	<0.001	<0.001		<0.06	<0.001	<0.001

a – least squares means within a column without a common superscript letter were significantly different at P <0.05.

Table 2 Effect of the average maximum temperatures before and after birth on milk yield of daughters in different farms

Temperature	A				B				C			
	effect of avg. max. temp. 6 wks.				effect of avg. max. temp. 6 wks.				effect of avg. max. temp. 6 wks.			
	n	before birth (kg)	n	after birth (kg)	n	before birth (kg)	n	after birth (kg)	n	before birth (kg)	n	after birth (kg)
Below 5 °C	44	5,617 ±305^{ab}	41	5,943 ±260^{a}			22	9,928 ±388^{a}				
5.1–14 °C	31	5,654 ±234^{a}	26	6,000 ±248^{a}	62	9,677 ±241^{a}	53	9,652 ±256^{a}	20	9,788 ±476^{a}	27	9,628 ±339^{a}
14.1–20 °C	22	5,316 ±286^{ab}	40	5,172 ±203^{ab}	37	9,590 ±264^{a}	22	9,533 ±281^{a}	27	9,550 ±343^{a}	21	9,674 ±326^{a}
Above 20 °C	30	5,148 ±317^{b}	20	4,565 ±334^{b}	43	9,245 ±313^{a}	53	9,235 ±286^{a}	68	10,279 ±398^{a}	68	10,339 ±361^{a}
p value		<0.66		<0.01		<0.59		<0.61		<0.38		<0.4

a–b – least squares means within a column without a common superscript letter were significantly different at P <0.05

Table 3 Impact of temperature 6 weeks before birth on heifers' birth weight

Temperature	*n*	Weight at birth (kg)
Below 5 °C	–	–
5.1–14 °C	62	42.3±0,5
14.1–20 °C	37	42.5±0,7
Above 20 °C	43	42.8±0,7
p value	<0.97	

Table 4 Impact of birth season on birth weight of heifers

Season	*n*	Weight at birth (kg)
Spring	38	42.5 ±0.7
Summer	32	42.3 ±0.7
Autumn	41	42.8 ±0.7
Winter	39	42.9 ±0.6
p	<0.74	

Table 5 The effect of average daily weight gains until weaning on first lactation milk yield of heifers

Average daily weight gain till weaning (kg)	*n*	305d milk yield (kg)
Bellow 0.7	15	9,539 ±428
0.7–0.9	84	9,067 ±204
0.9–1.0	39	9,457 ±248
Above 1.0	12	9,954 ±460
p value	<0.20	

day until weaning had in average higher milk yields on their first lactation. However, our findings in terms of growth might be altered by other factors, for instance by health status of the calves (Strapák et al., 2013).

4 Conclusions

Several authors point on importance of environmental factors, in particular on effect of season, prenatal and postnatal temperatures, that might be causing epigenetic modifications and subsequently affecting born heifers' performance. Our data from practical conditions indicate that season of birth and postnatal temperatures of dams' heifers may influence their first lactation milk yield. In terms of prenatal temperatures and weight gains of heifers until weaning we found only numerical similarities with earlier studies, that examined effect of these factors on first lactation milk yield.

Our results might be supported by earlier observations of other authors. However, further investigation preferably on higher number of animals, observing wider variety of factors is needed to enable us to assess more closely impact of prenatal and postnatal environment on milk yield of born heifers.

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